DESTINATION: restoration

COVER STORY

Edward Cass, Paratherm, USA, discusses how to replace fluid and restore performance in fouled heat transfer systems.

Thermal fluid systems are amongst the safest and most reliable heating designs available for manufacturing operations. Many factors contribute to the expected lifetime of the fluid and sooner or later the fluid suffers some degree of degradation or contamination, leading to a loss of performance and the need for replacement. In cases of severe degradation, performance may not be restored by a simple 'drain and refill,' and a more thorough cleaning of the system may be necessary. Restoration of performance can be achieved by identifying the root-cause of the degradation and applying the appropriate remedies. This article will discuss best practices for cleaning, flushing, draining, and recharging a thermal fluid system, and recommended practices to sustain performance.

Sources of degradation

Thermal degradation (overheating) occurs when fluid molecules absorb more thermal energy than they can effectively release. The excessive thermal stress cleaves molecular bonds, resulting in irreversible damage to the fluid and changes in physical properties. As fluid molecules become fragmented, they form lower molecular weight species (low boilers) which can also recombine to form higher molecular weight species (high boilers). Eventually, solubility limits may be exceeded, and high boilers can precipitate out as sludges and tars, potentially fouling heat exchange surfaces or plugging lines. In severe cases, thermal degradation can lead to heavy coking and potential failure of heater tubes. Thermal degradation rates can be minimised by: selecting the proper fluid based on the temperature requirements, never exceeding the manufacturers recommended maximum temperatures, and always ensuring adequate flow of the fluid through the heater. In addition, a routine preventative maintenance programme should be followed per original equipment manufacturer (OEM) recommendations.

Oxidative degradation occurs when hot fluid reacts with atmospheric oxygen in vented expansion tanks and reservoirs. Fluid oxidation can have significant impacts on fluid quality and performance. As oxidation proceeds, carbon soot and sludge may begin to accumulate, leading to significant increases in fluid viscosity, precipitation of sludge, and ultimately fouled surfaces and/or plugged lines. In most systems, oxidation can be eliminated by blanketing the expansion tank with an inert gas such as nitrogen. If blanketing is not an option, cold seal pots or thermal buffer tanks can be considered. Despite being easily remedied, oxidation accounts for >90% of all premature fluid degradation cases.

Contamination is typically caused by process leaks, or operational error, such as adding the wrong fluid to the system, sharing process equipment, or inadequate cleanout procedures. Dirt, rust, and pipe scale are also common contaminants that may be introduced during construction or maintenance of the system. The effects of contamination depend on the contaminant. Water contamination tends to manifest itself quickly, leading to pump cavitation, unexpected venting, or mechanical knocking. Other contaminants may degrade rapidly, leading to increased acidity, creation of low/high boilers, carbon generation and/or fouling of surfaces. Contamination can lead to reduced heat transfer rates, fouling, equipment failure and reduced operational safety.

Replacing the fluid

Once the thermal fluid has reached the end of its life, a plan for replacement should be determined. It is important to consider process down time (including cooling, draining, and filling), labour and

Figure 1. Sludge is formed over time as oxidation byproducts accumulate. Sludges are a significant detriment to performance, and often can shut systems down. Oxidation is eliminated with inert gas blanketing, or otherwise thwarted by filtration or reducing expansion tank temperatures.

Figure 2. Water will quickly manifest itself in high temperature thermal fluid systems. If water does get in the system in an appreciable concentration, it can only be removed with a controlled boil out procedure.

Figure 3. The expansion tank plays several key roles in the performance of the heat transfer system. When properly designed/configured, expansion tanks allow systems to run at low pressures, separate volatiles, and ensure the system is fully flooded.

safety provisions, third party contractors, and disposal costs, as well as the cost of the new fluid. It is possible that a simple drain and refill with continuous filtration is all that is necessary to restore performance. In other scenarios, a thorough offline cleaning procedure may be necessary. The disposal protocol should be reviewed for all fluid and cleaning agents used in the replacement process. Some recyclers will haul non-hazardous waste oil free of charge. Other fluids and chemical cleaning agents may require dedicated waste streams. Check with your suppliers and local regulatory authorities for more information.

Cleaning and restoring the system

Cleaning the system can be a very costly process. Completely plugged lines may have to be cut out and replaced or mechanically cleaned with high pressure water jets, steam lance, or abrasive blasting. In no-flow scenarios, equipment may need to be isolated or removed for cleaning. In scenarios where there is some flow, aqueous and organic cleaners can be effective for restoring performance.

Organic, non-aqueous additive cleaners are added to the existing fluid and the system is run at normal operating conditions. These cleaners loosen sludgy deposits from heat exchange surfaces and disperse solids for easier removal from the system. Once all the lines see restored thermal performance, the system is drained and recharged. Additive cleaning can be the most effective and efficient of options to get things turned around fast.

If the fluid viscosity is very high, or is a gel at room temperature, a suitable solvent or flushing fluid can be effective for thinning the incumbent oil and solvating tacky residues. Some solvent-like cleaning agents used at full strength may require a sacrificial flush volume (or two) to restore safe start-up conditions with fresh thermal fluid. Solvents are typically circulated at ambient temperature, and flow is maximised by isolating loops where possible. Extreme care must be taken when circulating flammable solvents. All effluent from the cleaning procedure must be handled, stored, and disposed of according to all applicable policies and regulations.

Other 'offline' cleaning methods include the use of aqueous solutions or other specialty full strength cleaners. One should proceed with caution when considering a water-based cleaning agent. Residual water can be difficult to remove, prolonging start-up to normal operations post-cleaning. Additionally, the rapid volumetric expansion of water to steam can lead to hot oil 'geysers' or explosive discharges if care is not taken. Consider scavenging residual water with a polar organic solvent and blow dry with nitrogen or air. During start-up, residual moisture must be boiled out of the system through the expansion-tank vent or other high point vents. For optimal efficiency, the expansion tank temperature must be maintained over 212°F and condensation of the steam inside the tank must be minimised. Warm-up/vent lines (which run from the heater outlet to the expansion tank) are the most effective setup. De-aerators do an excellent job of separating air and other non-condensing gases from fluid but may be less effective for venting a condensable like steam.

Fluid removal

For best results, ensure that all cleaning and draining cycles are as effective as possible. Install additional low point drains if necessary and open all high point vents for gravity draining. Keep the fluid turbulent as long as possible while draining. In the absence of dedicated drain provisions, be prepared to break flanges, open pressure taps, or remove valves, flex hoses, or other components from the piping to ensure complete fluid removal. Blowing out the lines with compressed air/nitrogen to force the fluid out one end of an open loop can be effective. Draining the system warm/hot (where applicable) will leave less fluid and solids in the lines than draining it cold. Shut the heater down and continue to run the pump until the fluid has cooled to below 82 – 93°C (180 – 200°F) and then drain as quickly as possible. Exercise caution and wear appropriate PPE when working with hot fluid and hot surfaces.

Charging and initial run

Prior to recharging, make any piping/design/maintenance modifications that may be advantageous while the system is in this docile state and make them accordingly (i.e., adding inert gas blanketing, new block valves, heater inspection, improved drainage, etc.). Replace all filter cartridges and pump strainers and open the filtration loop. New heat transfer fluid is best introduced using an external positive displacement pump and braided transfer lines connected as close as possible to the main pump suction to fill from low to high. Open all control and block valves and high point vents. Be prepared to monitor system vent points and catch/collect any fluid running out of vents as needed. Add fluid until the expansion tank is about half full. If the expansion tank level is hard to determine, look for overflow from the expansion tank vent. The pump discharge valve can be throttled to aid in priming and initiating flow. Add more fluid as needed if the low-level switch trips or the pump starts to cavitate. Once the fluid is circulating steadily through all loops, open the discharge valve another small increment, continuing to add fluid as needed. The system is full when the pump runs steadily with the block valve fully opened. Ensure that all lines are flooded. Add fluid to reach the proper level in the expansion tank, typically two-thirds to three-quarters full at maximum operating temperature. Ensure all safety, control and bypass valves have been restored to their 'normal' configuration.

Maintaining performance

Going forward, proactive maintenance and management is the most effective way to maximise performance of the heat transfer system. It is important to keep up with OEM preventative maintenance schedules, and to install inhouse proactive maintenance for the system. Most fluid suppliers offer an analysis programme for customers. These tests should be baselined to unused fluid for proper interpretation of results. Ongoing performance of the system and fluid can be optimised by monitoring cycle times, reducing pressure drops, reducing thermal cycling, and routinely monitoring for anomalies. With proper maintenance practices and routine condition monitoring, costly restoration of the system can be avoided in the future. T&T

Start-up tips

- If the expansion tank vent discharges into a catch tank, ensure that you can see the end of the pipe and that the system catch tank is completely empty.
- Open the manual valve on the expansion tank vent line. If you have a nitrogen blanket on the tank, set the nitrogen inlet pressure control valve as low as possible to provide a continuous purge through the vent – this will prevent oxidation of the fluid and speed up water removal.
- Lay welding blankets on top of the expansion tank to reduce condensation. Start the heater and increase the setpoint slowly to 100 – 104°C (212 – 220°F). Pump noise or pressure fluctuations, crackling or popping noises and/or sudden level changes in the expansion tank are all signs that there is water in the fluid.
- Throttle the pump discharge to establish flow through all loops of the system.
- The heater should remain in low fire until pump discharge pressures are stable at >121°C (250°F).

Shut-down tips

The performance and operating life of a heat transfer fluid can be maximised by paying close attention to system shutdown procedures. Otherwise, the fluid can be overheated and 'bruised,' and the system itself may ultimately be damaged.

During operation, both the heater's refractory and structural metal become almost as hot as the flame itself. If the entire system is shut down at once, the heater stops firing and the pump ceases to move the fluid. The intense heat stored in the heater's refractory and structural metal cannot quickly exit the stack and remains in the firebox – scorching the heater tubing and cooking the thermal fluid inside.

When shutting the system down, it is very important to turn the heater off but keep the circulating pump running. When the heater outlet temperature has decreased to 104°C (220°F) or lower, it is generally safe to shut the pump down. If possible, keep the heater blower running. By forcing cool air into the firebox, heat can be more quickly pushed out of the stack.

Bibliography

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